2008 NIOSH DREAM Workshop

Session 3:
Ergonomics and Vibration

Direct measurement of force exposure in hand tool use

Ray McGorry

Liberty Mutual Research Institute for Safety

Hopkinton, MA

November 13-14, 2008
Washington, DC

Workshop Goals

"Develop practical and consistent methods for objectively measuring physical stress….and for quantifying occupational exposure…."

"… to understand the quantitative exposure or dose-response relationships between

(1) exposure to external loads in the workplace and the resultant three-dimensional internal loads and physiological responses and

(2) exposure to external loads in the workplace and pain, discomfort, impairment, and disability. …"

Exposure to external loading

Survey of Ergonomists (CPEs)

- Observation / Subjective ratings
  - Frequent use
  - Video, checklists, tools (RULA, HAL)
- Psychophysical estimates
  - Occasional use
  - Hand and pinch grip dynamometers
- Direct measures
  - Infrequent use – due to expense, availability, lack of expertise (scales, push pull gauges were more commonly used - where applicable)

Dempsey et al. Applied Ergonomics, 2005; 36:489-503

LMRIS Direct reading program

Force exposure measurement with single-handled tools

- Many hand tool tasks are associated with repetitive strain injuries
- Exposure is difficult to measure
- Goal - measure grip force and applied moments during hand tool use, in the field and in the lab

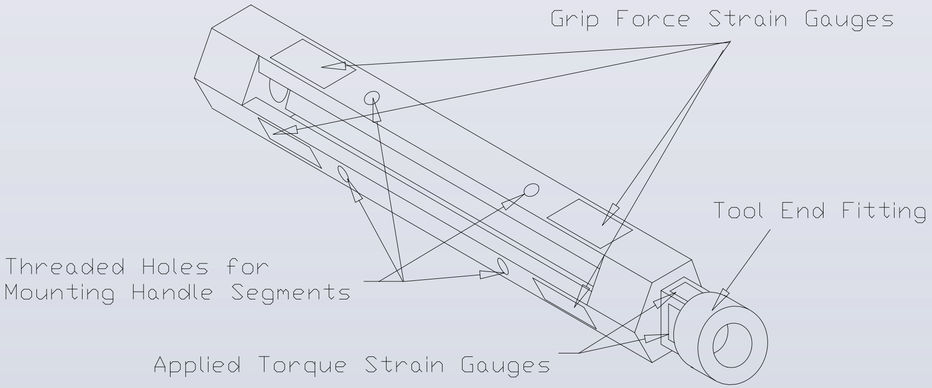
Design of measurement system

- Design constraints
  - Preserve original characteristics of the tool handle and end effector
  - “Universality”
  - Size, weight, cabling, handle configuration
  - Number of sensors
  - Durability
  - Fabrication and cost
- Several generations of designs

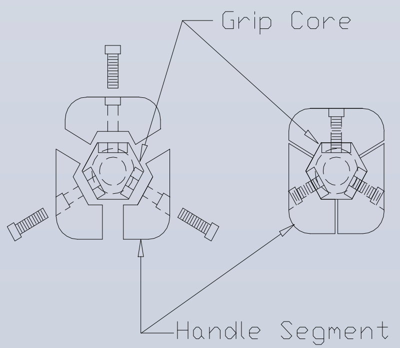
McGorry RW. Applied Ergonomics. 2001;32:271-279.

Design concept

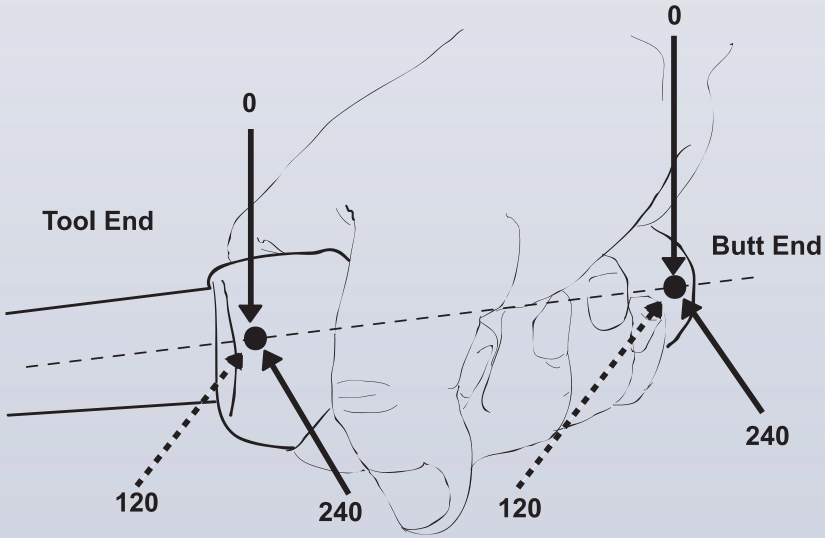
Perspective View

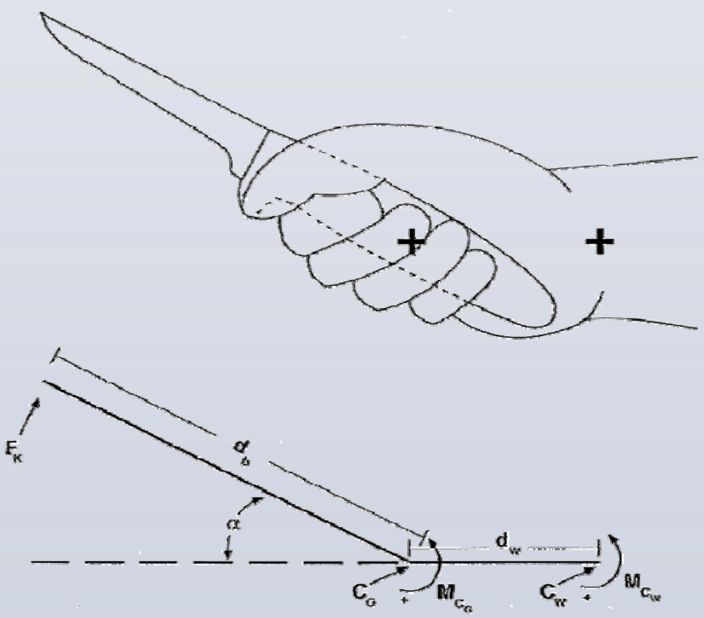


End View - Cut Away



Design concept





Current design

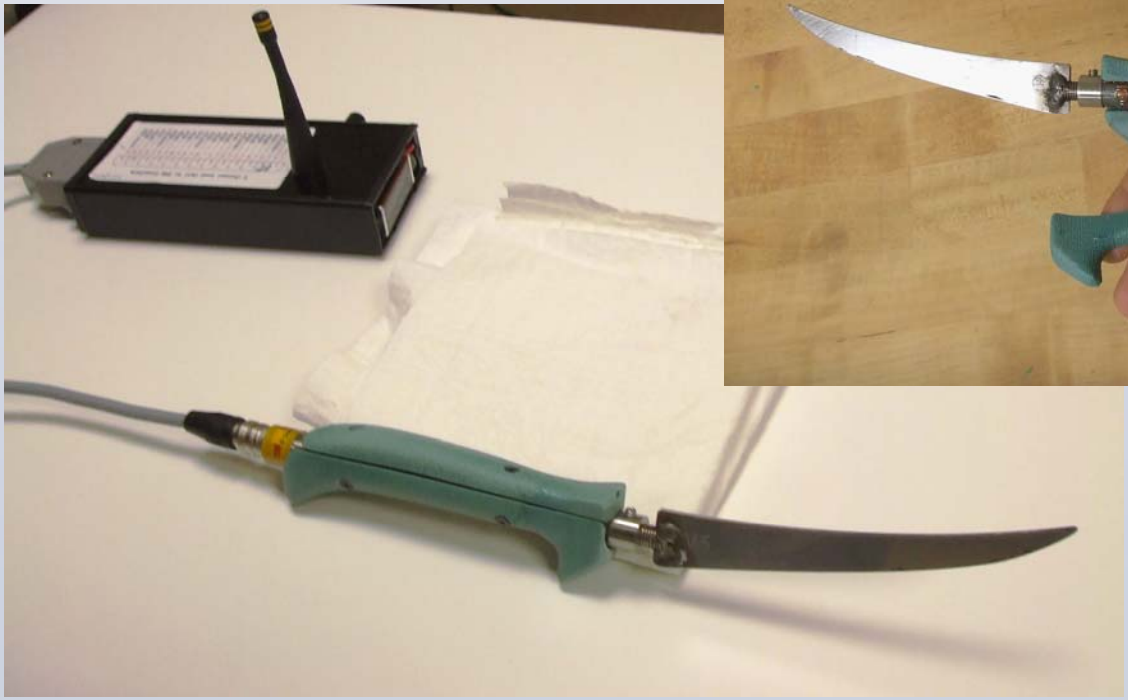
- Titanium core – 12.5 mm diameter
- Grip force – 3 suspended beams, strain gauges at both ends
- Moment (x and y) and axial torque at tool end

Current design

- Female mold of tool handle made in silicon
- Polyurethane casting material, poured around instrumented core blank
- Casting split into three parts

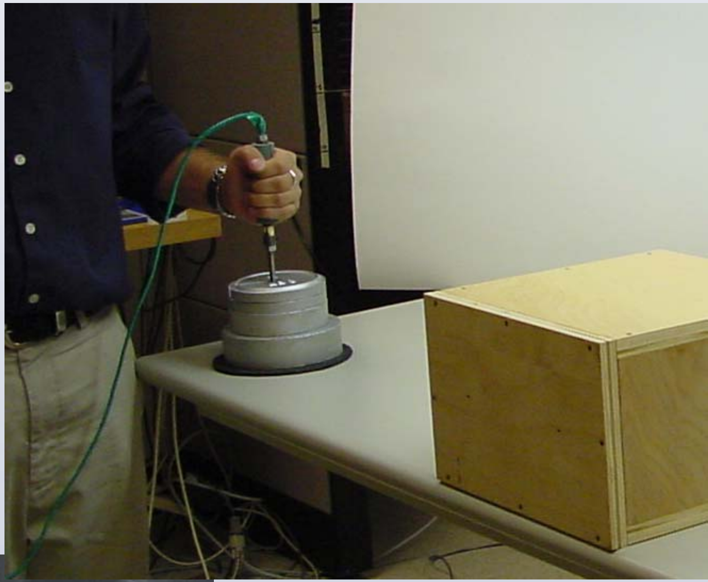
Current design

- **Tool end effector welded to threaded stud**
- **Cable connected to transmitter**



Psychophysical estimates

How well do people estimate grip force when using hand tools?



Psychophysical estimates

Results

- Large individual variability in estimates
- More accurate estimates of mean force than peak force
- Dependent on how force is applied

Casey et al., Prof Safety, 2002;47:18-24

McGorry et al., J Occup Rehab, 2004; 14:255-266

Psychophysical estimates

Individual variation in psychophysical estimate of grip force

% Estimation Error

Subject	**Mean Grip Force**	**Peak Grip Force**
1	79.9	3.6
2	65.0	11.3
3	39.8	-16.3
4	-51.9	-71.1
5	7.6	-40.1
6	4.8	-40.2
7	25.2	-34.3
8	-52.9	-74.2
9	-48.2	-70.4
10	-32.6	-62.2
11	7.0	-38.8
12	-28.8	-62.2
13	-3.3	-48.0
14	-4.0	-46.3
15	-38.8	-64.2
16	-46.3	-72.9
Mean (s.d.)	**-4.8 (41.5)**	**-45.4 (26.3)**

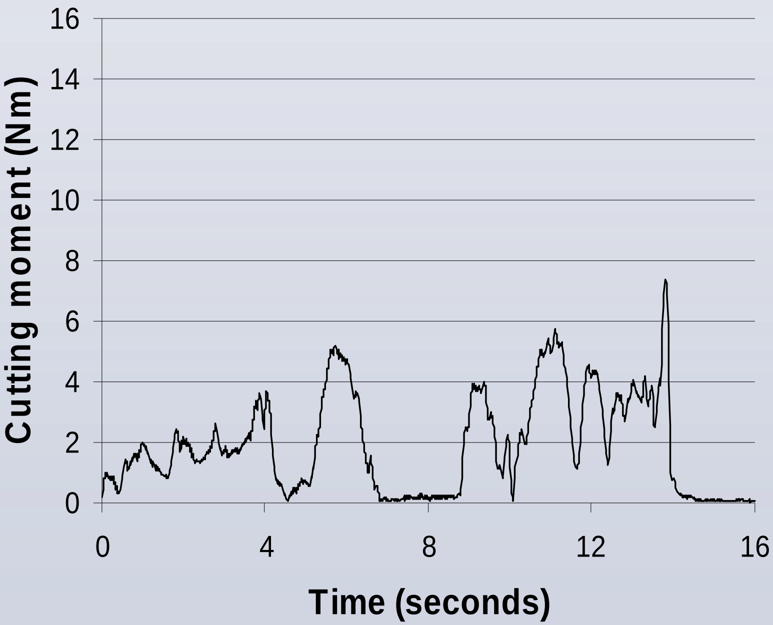
Percent estimation error = (actual grip force - estimate) / actual grip force, expressed as a percentage. A negative value represents an underestimation.

Casey et al., Prof Safety, 2002;47:18-24

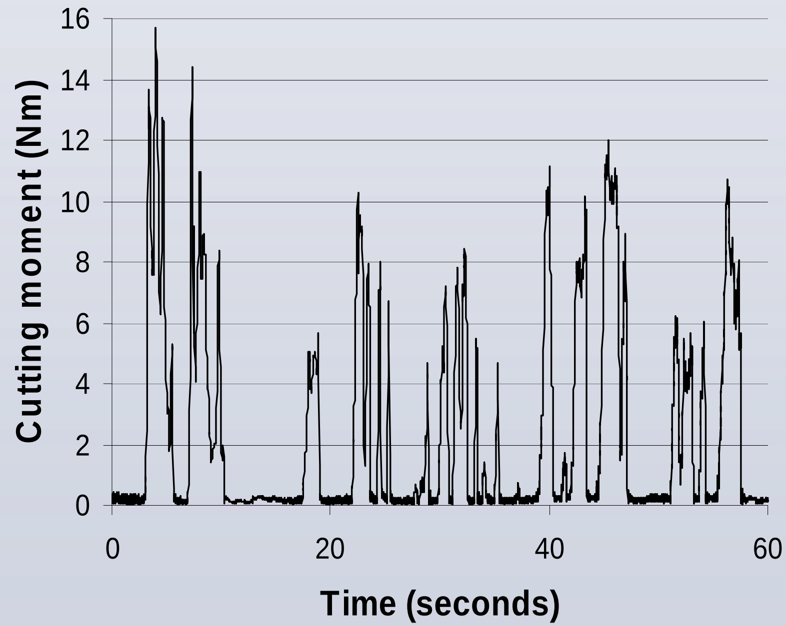
Field studies – meat cutting

Field studies – meat cutting

Two operations – two patterns of force application



Lamb Y-cut

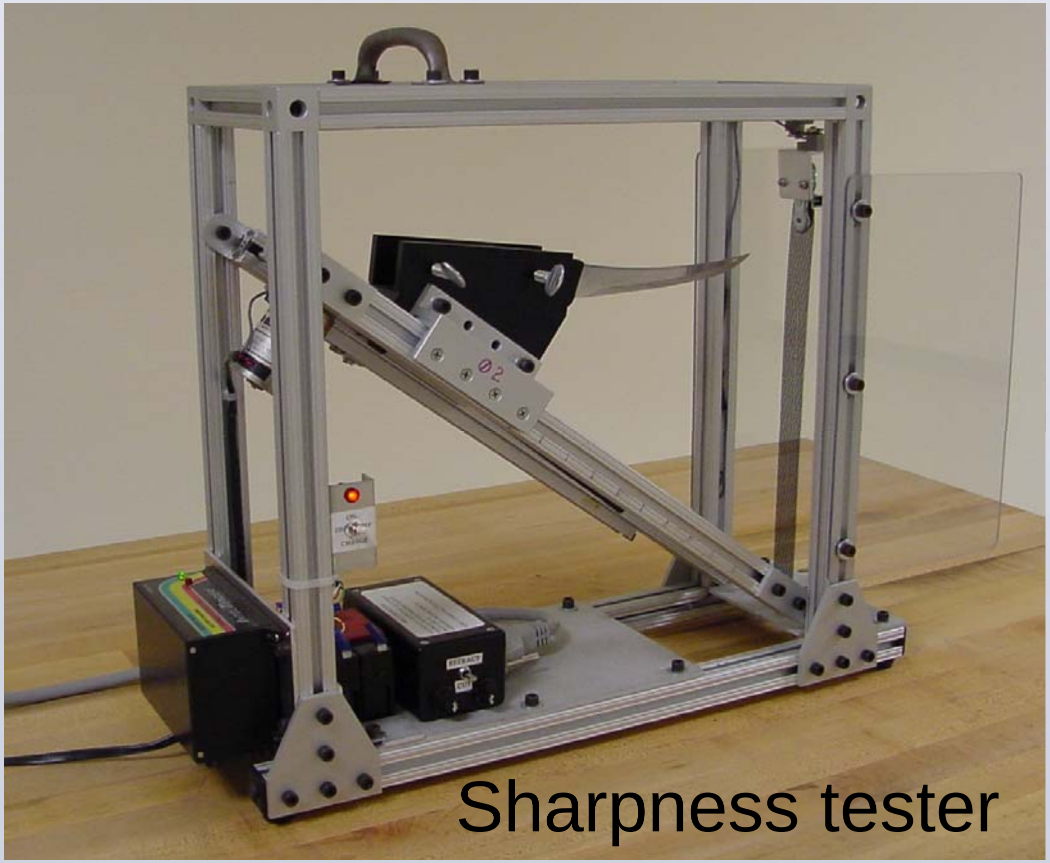


Lamb shoulder fleecing

McGorry et al., Applied Ergonomics. 2005;36:71-77

Field studies – meat cutting

Effect of blade sharpness



Sharpness tester

McGorry et al., Applied Ergonomics. 2003;34:375-382

Field studies – meat cutting

Effect of blade sharpness

	Grip Force (%MVC)		Cut Moment (%MVC)	
	Average	**Peak**	**Average**	**Peak**
Operation				
Shoulder	27.2 (11.9)	85.8 (32.0)	35.9 (10.9)	130.7 (32.0)
Rib	32.0 (12.7)	66.8 (20.9)	28.3 (8.9)	109.8 (23.9)
Loin	24.8 (4.4)	60.3 (20.3)	23.1 (3.9)	104.1 (17.7)
Sharpness				
Sharp	25.5 (10.2)	64.9 (27.9)	25.9 (9.2)	101.8 (24.9)
Dull	29.8 (12.1)	76.9 (31.4)	31.4 (9.7)	127.4 (29.0)

Blade dulled by one pass through 400 grit sandpaper.

McGorry et al., Applied Ergonomics. 2003;34:375-382

Field studies – meat cutting

Effect of blade sharpness

Mean differences and percent change due to blade sharpness

Dull vs. Sharp Blade	**Mean (s.d.)**	**% Change**	***p***
Sharpness score (N)	3.5	25	**< 0.0001**
Cutting Time (sec)	4.8 (6.4)	37	**0.012**
Peak Cutting Moment (Nm)	3.3 (2.9)	30	**0.001**
Mean Cutting Moment (Nm)	0.9 (0.9)	33	**0.014**
Peak Grip Force (N)	17.2 (38.9)	24	0.116
Mean Grip Force (N)	6.1 (9.9)	21	**0.038**

Blade dulled by one pass through 400 grit sandpaper.
Significant results indicated in ***bold*** *text.*

McGorry et al., Applied Ergonomics. 2003;34:375-382.

Field studies – meat cutting

Effect of experience

Dempsey and McGorry, J Occ Env Hyg, 2004, 1;167-172

Lab studies – pneumatic nutrunner

ISO 6544

Hand-held pneumatic assembly tools

for installing threaded fasteners –

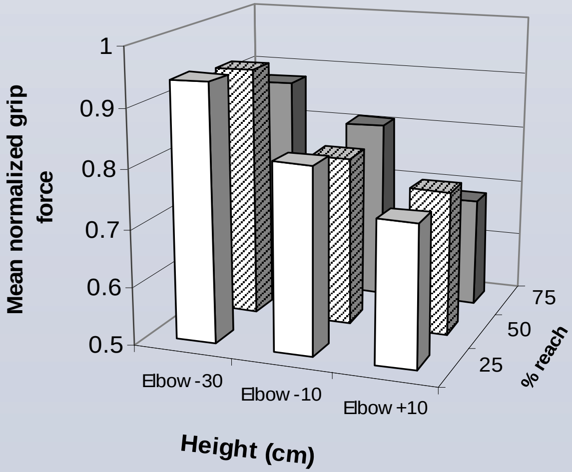
Reaction torque and torque impulse measurements

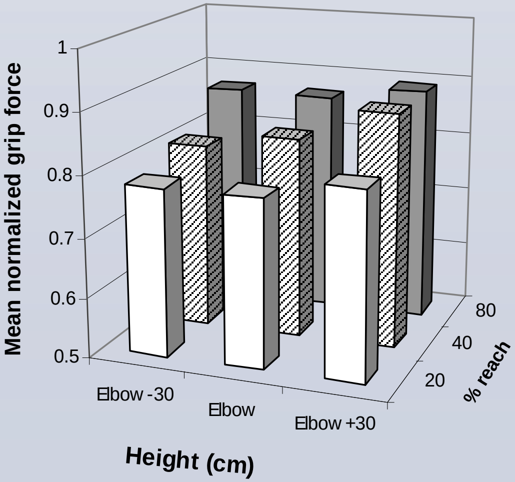
- *“Nor are there at the time of writing this International Standard, any known devices for measuring torque and force that can be used between the tool and the operator.”*

- Lin, J-H, McGorry RW, 2007. Hand-handle interface force and torque measurement system for pneumatic assembly tool operations: a supplement to ISO 6544. Journal of Occupational and Environmental Hygiene, 4, 332-340.

Lab studies – pneumatic nutrunner

Grip force vs. work orientation and position





McGorry and Lin. Ergonomics, 50, 1392-1403, 2007

Lab study - simulated meat cutting

Work station and task variables

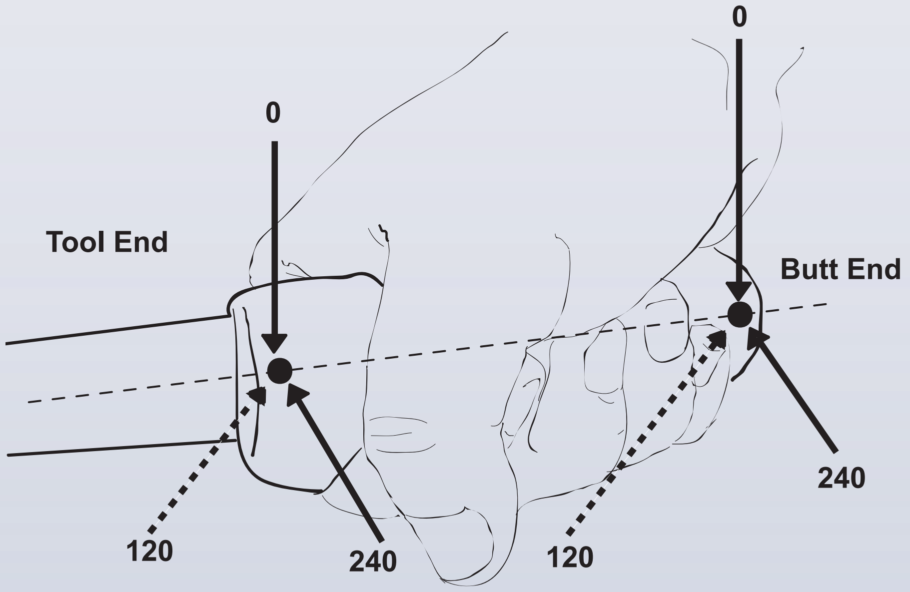
McGorry et al., Ergonomics, 2004; 47:1640-1656

“Efficiency” of force application

Mean cutting moment and grip force for a lab simulation (pacing) and two meat cutting operations

	Mean Cut Moment (Nm)	Mean Grip Force (N)	Grip to Cut Ratio
Task Pace			
Self	5.8 (1.2)	46.6 (14.4)	**8.0**
Production	6.8 (1.4)	58.9 (14.6)	**8.7**
Meat packing			
Shoulder cut	4.7 (1.1)	41.6 (10.8)	**8.8**
Loin trim	2.3 (0.4)	31.2 (3.9)	**13.6**

Distribution of forces



Peak force distribution (% of total) across six sensors

	0 Tool	0 Butt	120 Tool	120 Butt	240 Tool	240 Butt
Simulated cutting (lab)	62.1	2.3	0.0	11.7	6.1	17.8
Meat cutting (packing plant)	64.4	8.9	0.0	8.9	0.0	17.8
Ratchet	0.0	35.9	20.3	7.8	25.0	10.9
Screwdriver	1.0	25.7	8.4	29.8	7.3	27.8

Laboratory studies

- Pneumatic nutrunners
  - Lin et al., Ergonomics. 50, 859-876, 2007
  - Lin and McGorry. J Occup Envir Hygiene, 4, 332-340, 2007
  - McGorry and Lin. Ergonomics, 50, 1392-1403, 2007
- Ice cream scooping
  - Dempsey et al., Applied Ergonomics, 2000;31:121-130
- Screwdriver, ratcheting
  - McGorry et al., J Occup Rehab, 2004; 14:255-266

Present work

- ACGIH TLV – Hand Activity Level
  - Uses expert rating of task demand, Borg Scale (0 -10) or psychophysical estimate
  - Initial report - comparison of direct measure to Borg scale and psychophysical estimates - 16 subjects, multiple tasks
- NIRS and tissue perfusion in the upper extremities

Future work

- Collaboration with GTRI - poultry processing plants in southeastern USA
  - Determine exposure levels
  - Examine safety margin
  - Investigate training, job rotation as potential interventions
  - Evaluate intervention

Where do we go from here?

- What are your thoughts on future technological approaches, what exposures to assess, etc.?